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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 5 : B29C 67/14 — A1

(11) International Publication Number: WO 91/06421

(43) International Publication Date: 16 May 1991 (16.05.91)

(21) International Application Number: PCT/GB90/01671

(22) International Filing Date: 1 November 1990 (01.11.90)

(30) Priority data:
8924590.6 1 November 1989 (01.11.89) GB

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(81) Designated States: AT (European patent), AU, BE (European patent), BR, CA, CH (European patent), DE (European patent), DK (European patent), ES (European patent), FI, FR (European patent), GB, GB (European patent), GR (European patent), HU, IT (European patent), JP, KR, LU (European patent), NL (European patent), NO, SE (European patent), SU, US.

Published
With international search report.

(54) Title: REINFORCED COMPOSITE STRUCTURAL MEMBERS

(57) Abstract

Composite structural members moulded or pultruded from plastics or ceramic material and containing fibre reinforcement configured such that in flange portions of the member reinforcing fibres lie predominantly at angles of 0° to 90° to an axis of the member whereas in web portions the reinforcing members lie predominantly in directions oppositely inclined to the axis, each at an angle in the range 30° to 80°. Reinforcing fibres are made up by, for example, knitting, braiding or weaving, into a preform having the desired fibre configuration, the preform being laid in a mould, pulled through a die or otherwise introduced during manufacture in any convenient manner. Highly accurate fibre placement is possible yielding greatly improved strength as compared with conventional techniques, at joints between web and flange portions of the member.

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"REINFORCED COMPOSITE STRUCTURAL MEMBERS"

This invention relates to reinforced composite structural members and, more particularly, to a fibre reinforcement preform configuration for moulded or pultruded composite structural members in which reinforcing fibres are configured in a way which not only confers optimal bending and shear properties in each member but also provides greatly improved strength in junctions between web and flange portions of each member.

Moulded or pultruded composite structural members are known in which woven reinforcing mats, knitted reinforcing mats, continuous filament mats and many other reinforcing mat forms are used to reinforce the structural members. These mats are laid or pulled into moulds and bent around corners to provide reinforcement. Although reinforcement direction and quantity can be varied in different portions of members to suit the stress levels and directions, the junctions between different portions cannot be reinforced satisfactorily to provide high out of plane distortional bending strength or local tensile strength where for example forces are trying to pull flange from webs. In order to try to overcome these problems knitted, braided and woven preforms are known in which, in addition to reinforcing fibres running in the plane of flange and web portions, fibres are either knitted, braided or woven through the thickness of member portions to improve their strength. Unfortunately these braiding, knitted and weaving processes degrade the axial strength and stiffness of the structural members because fibres

are not fully continuous in the plane of the member flange and web portions. Fibres are continually woven back through the thickness of the member faces rather than continuing in place. These kinks in the fibres cause loss of strength, the matrix properties become more important because of stress transfer at the changes in fibre direction and therefore properties become more sensitive to matrix degradation. Overall stiffness is reduced because of fibre discontinuities.

According to this invention, we propose a composite structural member comprising a fibre-reinforcement preform according to any preceding claim, embedded in a matrix material.

Also according to the invention, we propose a fibre-reinforcement preform for use in the manufacture of a reinforced composite structural member having a web portion and a flange portion, the preform comprising a flange reinforcement portion wherein reinforcing fibres lie parallel to an axis of the preform and overlap reinforcing fibres that lie at right angles to the said axis, and a web reinforcement portion wherein reinforcing fibres, overlap in directions oppositely inclined to the said axis, each of said opposite directions being inclined to the said axis at an angle of 30° to 80°.

One advantage of the use of such a reinforcement preform is the improvement in accuracy of fibre placement at joints between flange and web portions compared to the prior art.

There may be one or more layers of fibre, preferably glass fibre reinforcement in either or both of the web and flange portions depending on the particular application. Also, web reinforcement fibres may be positioned to lie symmetrically at angles of +X and -X degrees to the axis, and the value of X (between 30 and 80 degrees) may be selected as appropriate to a particular application. The main reinforcing fibres, which may be any suitable material are preferably continuous fibres which are only kinked from their straight predetermined directions at the web-flange portion junctions and at the edges of flange and edges of the web portion outstands. The angled straight reinforcing fibres in the web portions may pass up and down these portions alternately and loop around the 90 degree fibres which are closest to the outside face of the flange portions opposite the web portions. The reinforcing fibres in the flange portions lying at 90 degree to the member axis are laid backwards and forwards across these portions and are looped around and back on themselves at the flange portion edges. The reinforcing fibres in the flange portions lying at 0 degree to the member axis are each continuous along the length of the preform.

The looping of the angled web portion reinforcement around the outer 90 degree flange portion reinforcement provides a strong direct connection between web and flange portions while at the same time keeping reinforcing fibres straight in all the main member portions. The type of reinforcing fibres used, the quantity and angle of web reinforcement can all be varied to optimise the structural design of any member. Hence an

optimised structure with respect to overall strength and stiffness for given material content can be achieved with superior connection strength and stiffness between web and flange portions compared to the prior art described above. This reinforcement configuration can be used in any structural composite member formed by moulding or pultrusion using any matrix including plastics and ceramics. Member geometry can either vary along the member axis or can be constant as is more usual with pultrusion.

In a preferred embodiment at least two layers, each layer containing +X and -X degree angled reinforcement, in each web portion are spaced from each other using a spacing mat which is able to absorb matrix material during the moulding or pultrusion operation. The fibre reinforcement may be configured as described above, with the web portion reinforcement looped around the 90 degree fibres in the flange portions, but with the positions where web reinforcement layers loop around the flange reinforcement spaced using the spacing mat. The spacing of these reinforcement connections further increases the strength of the flange to web portion connections in bending in cases where high transverse bending is present in the section due to distortion caused by local loading or where high post buckling reserves of strength are required.

Where web and flange portions are reinforced as described above and a flange portion is connected to the face of a web portion which continues above and below the flange, the 90 degree fibres

in the flange portion are looped around the diagonal web fibres which are closest to the outside face of the web portion opposite the flange portion.

The invention also includes a composite structural member comprising the fibre reinforcement preform referred to above, embedded in a matrix material.

Embodiments of the invention will now be described by way of example with reference to the accompanying drawings in which:-

Figure 1 is an isometric view of a 'Tee' junction between web and flange portions of a composite member, reinforced with fibres;

Figure 2 is a cross-section through the flange portion shown in Figure 1 showing also an elevation on the web portion with the fibre reinforcing configuration indicated;

Figure 3 is an isometric view of an 'L' junction between web and flange portions of a composite member, reinforced with fibres;

Figure 4 is a cross-section through a composite plank component as an example of the use of the reinforcement preform configuration;

Figure 5 is a cross-section through a composite connector component as a further example of the use of the reinforcement preform configuration;

Figure 6 is a cross-section through another composite section;

Figure 7 is a cross-section through a 'T' junction part of a composite member in which a spacing mat is used in the flange portion to increase connection strength;

Figure 8 is an isometric view of a junction between a flange portion and a web portion of a composite member in which the web continues above and below the flange and portions are reinforced in accordance with the invention; and

Figure 9 is a cross-section through a composite section for building and retaining wall applications.

Referring to Figure 1 of the drawings, a part of a complete composite structural member is shown having a flange portion 1 and a web portion 2. The matrix which may be of plastics or ceramic material, is assumed transparent for the purpose of illustration only. The flange portion has an edge 7, and is reinforced with three layers of glass fibre reinforcement. The first layer 4A is orientated at 90 degrees to the member axis 3 and is looped around 9 at the flange edge 7. The second layer 10 is orientated at 0 degrees to the member axis 3 and consists of continuous fibres running down the reinforcement preform. The third layer 4B is orientated at 90 degrees to the member axis 3 and is also looped around at the flange edge 7. The web portion 2 is reinforced with fibres 5A orientated at +X degrees

to the member axis 3 and fibres 5B orientated at -X degrees to the member axis 3. These diagonal fibres 5A and 5B in the web portion 2 are looped over the top layer of 90 degrees flange reinforcement 4A as indicated 6.

Referring to figure 2, the way in which the web fibres 5A and 5B are inclined at +X degrees, 8A and -X degrees, 8B to the member axis respectively is clearly shown. Also the way in which these fibres are looped over the transverse flange fibres 4A in flange portion 1 is also shown. The web reinforcing fibres 5A pass up between flange fibres 4B and 10 loop over fibres 4A and then pass back down again as fibres 5B. In this way the preform is woven from continuous fibres in a continuous operation.

Referring to Figure 3 of the drawings, the flange portion 11 stops at the line of the web portion forming an 'L' part of a complete composite structural member. The flange portion is reinforced with three layers of fibre reinforcement. The first and third layers 13A and 13B respectively are orientated at 90 degrees to the member axis 15 and the fibres are looped, 18, around at the outer corner of the 'L' section, 17. The second layer of fibres 19 is orientated at 0 degrees to the member axis. The web portion 12 is reinforced with fibres 14A orientated at +X degrees to the member axis 15 and fibres 14B orientated at -X degrees to the member axis 15. These diagonal fibres 14A and 14B in the web portion 12 are looped over the top layer of 90 degrees flange reinforcement 13A as indicated, 16.

Referring to Figure 4, a composite plank member is shown in cross-section having flange portions 22 spaced by web portions 23 and 24 joined at 'T' junctions 21 and 'L' junctions 20. A preferred reinforcement configuration for this plank is to manufacture a fibre reinforcement preform in which the flange and web portions and 'T' junctions 21 are reinforced as shown in Figure 2 and either Figure 1 or Figure 7 and the 'L' junctions 20 are reinforced as shown in Figures 2 and 3.

Referring to Figure 5, a composite connector member is shown in cross-section having flange portions 27 and 30 spaced by web portions 28 and 29 joined at 'L' junctions 25 and 26. A preferred reinforcement configuration for this connector is to manufacture a fibre reinforcement preform in which the flange and web portions and 'L' junctions 25 and 26 are reinforced as shown in Figures 2 and 3.

Referring to Figure 6, a new composite section is shown in cross-section in which flange portions 34A have outstanding portions which are heavily loaded in a manner which will try to tear them from the web portions 33. A preferred reinforcement configuration for this section is to manufacture a fibre reinforcement preform in which the flange portions 34A and web portions 33 and 'T' junctions 31 are reinforced as shown in Figure 2 and either Figure 1 or Figure 7. Also the 'L' junction 32 is reinforced as shown in Figures 2 and 3, and the other junction 32A is reinforced as shown in Figure 8.

Referring to Figure 7 a flange portion 35 is shown connected to a web portion 36. In this case two layers of web reinforcing fibres 40 and 42, each having fibres at +X and -X degrees to the member axis are shown. These web fibres pass up through the flange between fibres 38 and 39 and lop over the 90 degree flange reinforcement fibres 37. Web fibre layers 40 and 42 are spaced apart using a spacing mat 41 which increases the lever arm between the anchorages of the web fibres at the flange. This increases the capacity of the joint to resist out of plane bending effects.

Referring to Figure 8 of the drawings, a part of a complete composite structural member is shown having a flange portion 43 and a web portion 44 which extends above and below the flange portion. The flange portion is reinforced with three layers of fibre reinforcement. The first layer 45A and the third layer 45B are orientated at 90 degrees to the member axis 49 and are looped around, 48, the diagonal web portion reinforcing layer 47A which is closest to the outer web face. the second layer in the flange portion is orientated at 0 degrees to the member axis 49 and consists of continuous fibres running down the reinforcement preform. The web portion 44 is reinforced with fibres 47A and 47B orientated at +X and -X degrees to the member axis 49 respectively.

Referring to Figure 9 a composite section is shown in cross-section having flange portions 49, 51 and 52 and web portions 53,

54, 58, 59 and 60 joined to form a structural member suitable for construction of building frames and retaining walls. A preferred reinforcement configuration for this member is to manufacture a fibre reinforcement preform in which the flange and web portions and 'T' junctions 57 and 60 are reinforced as shown in Figure 2 and either Figure 1 or Figure 7, 'L' junctions 55 are reinforced as shown in Figures 2 and 3 and other junctions 56 are reinforced as shown in Figure 8.

The above description refers to the orientation of fibres in the web portions at angles of +X degrees and -X degrees to the member axis where X is chosen between 30 degrees and 80 degrees. The angle that is chosen will depend on the relative magnitudes of different design forces in each web portion in each application. The forces that generally influence the choice are shear force in the plane of the web portion and out of plane bending about axes in the plane of the web lying either parallel to the member axis or orthogonal to the member axis. In cases where shear predominates the preferred angle will be close to 45 degrees, in cases where bending about on axis parallel with the member axis predominates the preferred angle will be closer to 30 degrees and in cases where bending about on axis orthogonal to the member axis predominates the preferred angle will be closer to 80 degrees.

CLAIMS:

1. A fibre-reinforcement preform for use in the manufacture of a reinforced composite structural member having a web portion and a flange portion, the preform comprising a flange reinforcement portion wherein reinforcing fibres lie parallel to an axis of the preform and overlap reinforcing fibres that lie at right angles to the said axis, and a web reinforcement portion wherein reinforcing fibres, overlap in directions oppositely inclined to the said axis, each of said opposite directions being inclined to the said axis at an angle of 30° to 80°.

2. A preform according to claim 1 wherein the reinforcing fibres in the flange portions and/or in the web portions are woven.

3. A preform according to claim 1 or claim 2 wherein the inclined fibres in the web reinforcement portion are formed by one or more continuous fibres which extend in one of said oppositely inclined directions, pass over right angled fibres in the flange portion reinforcement and extend in the other of said oppositely inclined directions to an edge of the web portion configuration.

4. A preform according to claim 3 wherein at the edge of the web reinforcement portion, a fibre extending in one of said oppositely inclined directions loops back to extend in the other of said oppositely inclined directions.

5. A preform according to any preceding claim wherein right angle fibres in the flange reinforcement portion comprises one or more continuous fibres that loop back and forth across the flange portion configuration.

6. A preform according to any preceding claim wherein the parallel flange reinforcement portion fibres, comprises continuous fibres extending along the length of the preform.

7. A preform according to any preceding claim wherein a flange reinforcement portion is connected to a web reinforcement portion extending on opposite sides of the flange portion, the right angle flange portion fibres being looped around inclined web portion fibres.

8. A preform according to any preceding claim wherein fibres in the web reinforcement portion lie symmetrically at angles of +X and -X degrees to the axis, X being in the range 30° to 80°.

9. A preform according to any preceding claim comprising two or more layers of web reinforcement fibres from each other by a spacing mat.

10. A composite structural member comprising a fibre-reinforcement preform according to any preceding claim, embedded in a matrix material.

11. A composite structural member having a web portion and a flange portion, the member comprising a matrix of material in which is embedded at least one layer of fibre-reinforcement configured such that in the flange portion reinforcing fibres lie parallel to an axis of the member and overlap reinforcing fibres that lie at right angles to the axis, and in the web portion reinforcing fibres overlap in directions oppositely inclined to the said axis each of said opposite directions being inclined to the said axis at an angle of 30° to 80°.

12. A composite structural member according to claim 10 or claim 11 wherein reinforcing fibres in the web portion lie symmetrically at angles of +X and -X degrees to the said axis, X being in the range 30° to 80°.

13. A member according to any one of claims 10 to 12 and comprising two or more layers of web reinforcement fibres spaced from each other by a mat embedded in and impregnated by the said matrix material.

14. A member according to any one of claims 10 to 13 wherein the matrix is of plastics or ceramic material.

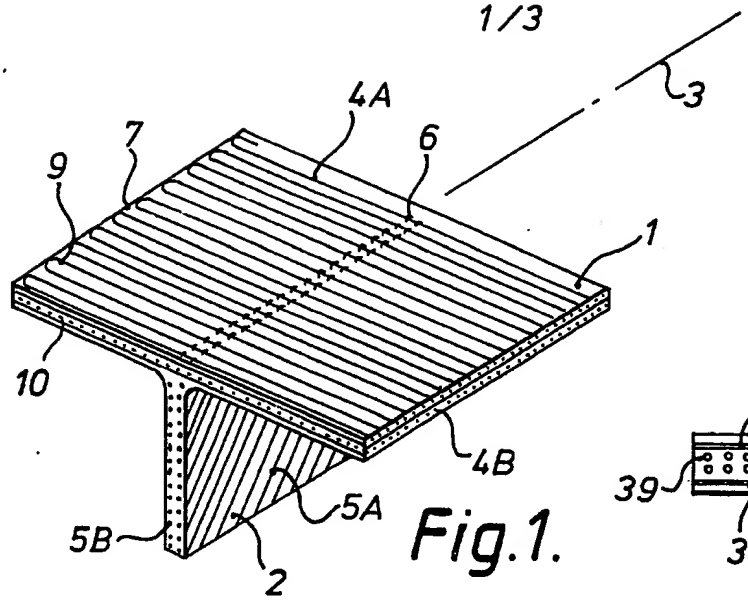

Fig.1.

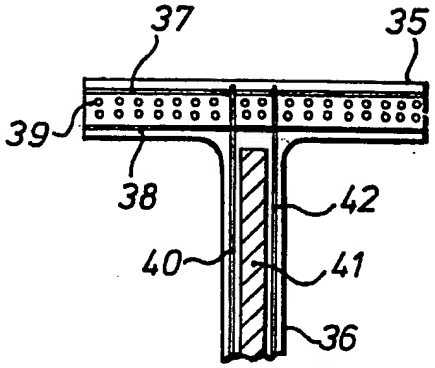

Fig.7.

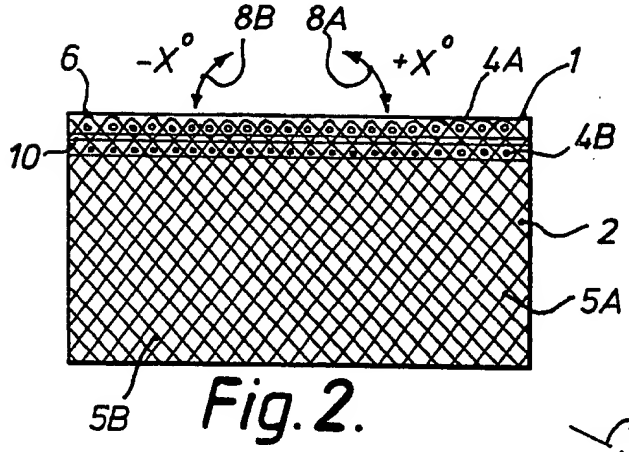

Fig.2.

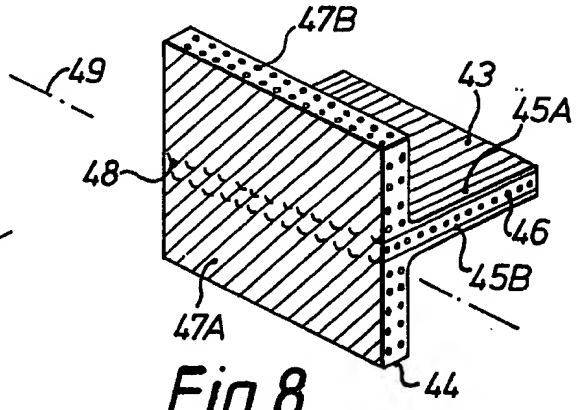

Fig.8.

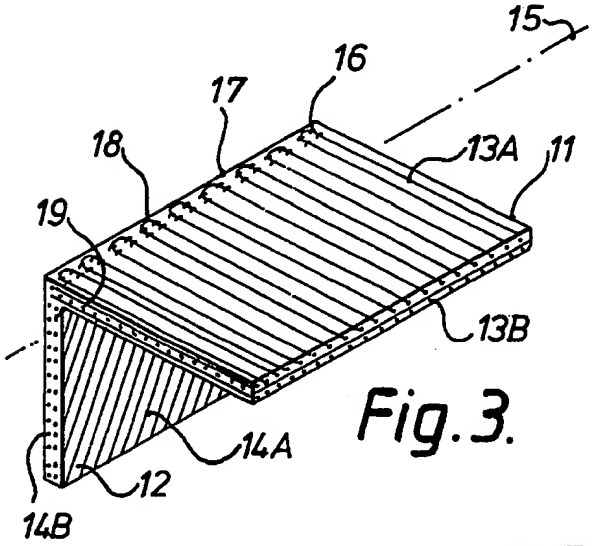

Fig.3.

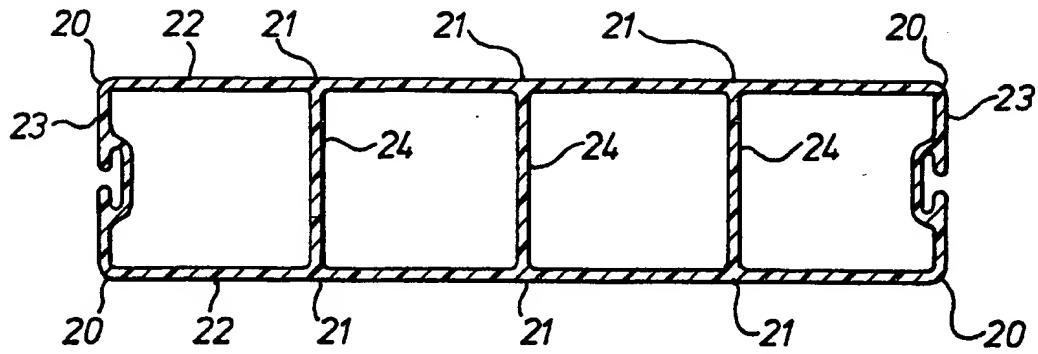

Fig.4.

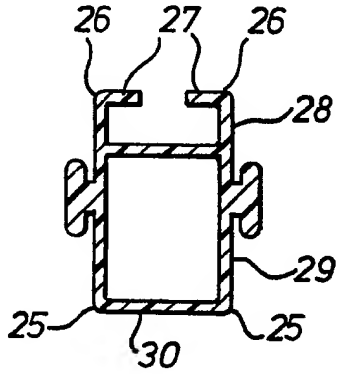

Fig.5.

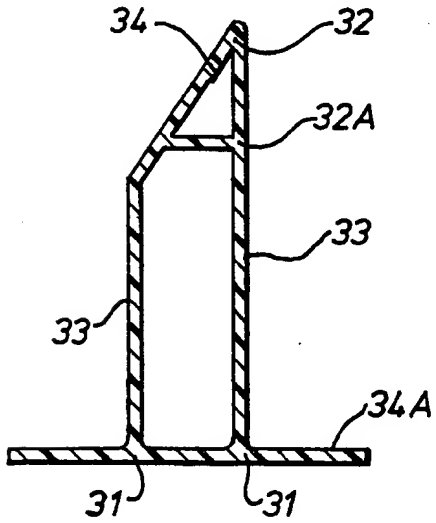

Fig.6.

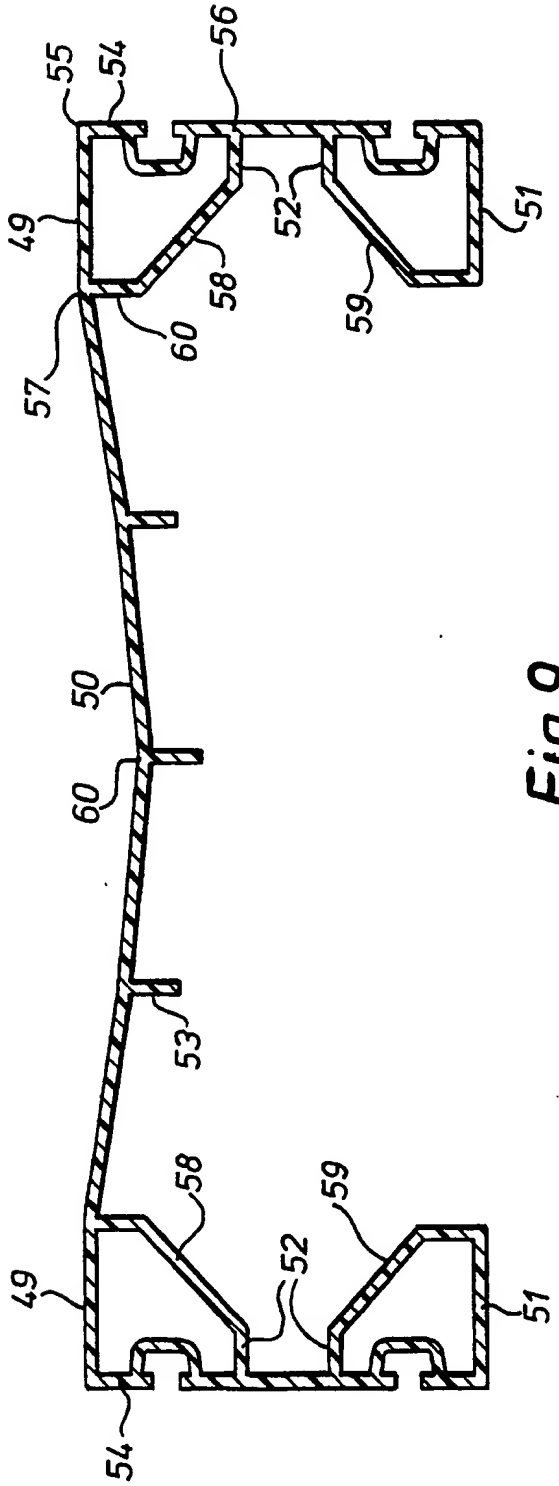

Fig.9.

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 90/01671

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[5]: B 29 C 67/14

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[5]	B 29 C, B 29 D

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	EP, A, 0236500 (SHIKISHIMA CANVAS KABUSHIKI KAISHA) 16 September 1987 see page 10, lines 13-21	1-5,7-8,10, 11,12,14
Y		9,13

X	EP, A, 0329434 (MITSUBISHI JUKOGYO KABUSHIKI KAISHU) 23 August 1989 see column 2, lines 39-44; claim 6	1-8,10,11, 12,14

X	DE, A, 2334645 (MASCHINENFABRIK AUGSBURG-NURNBERG) 16 January 1975	1,2,4-8,10, 11,12,14

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* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
28th January 1991	14. 02. 91
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	miss T. MORTENSEN

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 9001671 SA 41395

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 05/02/91
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